

APSIDAL MOTION AND LIGHT A CURVE SOLUTION FOR EIGHTEEN SMC ECCENTRIC ECLIPSING BINARIES

P. ZASCHE¹ M. WOLF¹ J. VRAŠTIL¹ J. LIŠKA² M. SKARKA² M. ZEJDA²

¹ Astronomical Institute, Charles University in Prague, Faculty of Mathematics and Physics,
 CZ-180 00 Praha 8, V Holešovičkách 2, Czech Republic

² Department of Theoretical Physics and Astrophysics, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic

(Dated: Received December 3, 2014)

Draft version December 3, 2014

ABSTRACT

Aims: The Danish 1.54-meter telescope at the La Silla observatory was used for photometric monitoring of selected eccentric eclipsing binaries located in the Small Magellanic Cloud. The new times of minima were derived for these systems, which are needed for accurate determination of the apsidal motion. Moreover, many new times of minima were derived from the photometric databases OGLE and MACHO. Eighteen early-type eccentric-orbit eclipsing binaries were studied.

Methods: Their $O - C$ diagrams of minima timings were analysed and the parameters of the apsidal motion were obtained. The light curves of these eighteen binaries were analysed using the program PHOEBE, giving the light curve parameters. For several systems the additional third light also was detected.

Results: We derived for the first time and significantly improved the relatively short periods of apsidal motion from 19 to 142 years for these systems. The relativistic effects are weak, up to 10 % of the total apsidal motion rate. For one system (OGLE-SMC-ECL-0888), the third-body hypothesis was also presented, which agrees with high value of the third light for this system detected during the light curve solution.

Subject headings: stars: binaries: eclipsing – stars: early-type – stars: fundamental parameters – Magellanic Clouds

1. INTRODUCTION

Other galaxies have become the most prominent battlefields in current astrophysical research, mainly due to the large and long-lasting photometric surveys. These surveys like MACHO or OGLE have discovered thousands of new eclipsing binaries in the Magellanic Clouds, hence, we know only about twice more eclipsing binaries in our own Milky Way than in other galaxies (see Pawlak et al. 2013, or Graczyk et al. 2011).

On the other hand, the chemical composition of the Magellanic Clouds differs from that of the solar neighborhood (e.g. Ribas 2004), and the study of the massive and metal-deficient stars in the SMC checks our evolutionary models for these abundances. All eclipsing binaries analysed here have properties that make them important astrophysical laboratories for studying the structure and evolution of massive stars (Ribas 2004).

Eccentric eclipsing binaries (hereafter EEBs) with an apsidal motion can provide us with an important observational test of theoretical models of stellar structure and evolution. A long-term collection of the times of EEBs minima observed for several years throughout the apsidal motion cycle and a consecutive detailed analysis of the period variations of EEB can be performed, yielding both the orbital eccentricity and the period of rotation of the apsidal line with high accuracy (Giménez 1994). Many different sets of stellar evolution models have been published in recent years, such as for Maeder (1999), or Claret (2005); however, to distinguish between them and to test, which one is more suitable, it is still rather difficult. The internal structure constants, as derived from the apsidal motion analysis, could serve as one independent criterion. On the other hand, only stellar param-

eters for EEBs with an accuracy of 1 % can be used to discriminate between the models.

Here, we analyse the observational data and rates of apsidal motion for eighteen SMC detached eclipsing systems. All these systems are early-type objects, having eccentric orbits, which also exhibits an apsidal motion. Similar studies of LMC EEBs have been presented by Michalska & Pigulski (2005), by Michalska (2007), and recently also by Zasche & Wolf (2013). As far as we know, only several eclipsing binaries with apsidal motion were analysed in SMC galaxy until now: SC3 139376, SC5 311566 (Graczyk 2003), and nine other systems by North et al. (2010).

2. OBSERVATIONS OF MINIMUM LIGHT

Monitoring of faint EEBs in external galaxies became almost routine nowadays with quite moderate telescopes of 1 - 2m class, which are equipped with a modern CCD camera. However, a large amount of observing time is needed, which is usually unavailable at larger telescopes. During the last two observational seasons, we have accumulated 2660 photometric observations and derived 29 precise times of minimum light for selected eccentric systems. New CCD photometry was obtained at the La Silla Observatory in Chile, where the 1.54-m Danish telescope (hereafter DK154) with the CCD camera and R filter was used (remotely from the Czech Republic).

All CCD measurements were reduced in a standard way using the bias frames and then the flat fields. The comparison star was chosen to be close to the variable one and with similar spectral type. A synthetic aperture photometry and astrometry software developed by M. Velen and P. Pravec APHOT, was routinely used for reducing the data. No correction for differential extinction was applied because of the proximity of the comparison stars

to the variable and the resulting negligible differences in air mass and their similar spectral types.

The new times of primary and secondary minima and their respective errors were determined by the classical Kwee-van Woerden (1956) method or by our new approach (see the section 4.2). All new times of minima are given in the appendix Tables 5.

3. PHOTOMETRY AND LIGHT CURVE MODELLING

The core of our analysis lies on the huge photometric data sets, as obtained during the MACHO (Faccioli et al. 2007), OGLE II (Wyrzykowski et al. 2004), and OGLE III (Graczyk et al. 2011) surveys. These photometric data were used both for minima time analysis and for light curve analysis. The method of how the individual times of minima for the particular system were computed is presented in section 4.2. Our new observations obtained at the Danish 1.54-m telescope were used only for deriving the times of minima for the selected targets.

The analysis of the light curves (hereafter LC) for the systems was carried out using the program PHOEBE, ver. 0.31a (Prša & Zwitter 2005), which is based on the Wilson-Devinney algorithm (Wilson & Devinney 1971) and its later modifications, but some of the parameters have to be fixed during the fitting process. The albedo coefficients A_i remained fixed at value 1.0, the gravity darkening coefficients $g_i = 1.0$. The limb darkening coefficients were interpolated from the van Hamme tables (van Hamme 1993), and the synchronicity parameters (F_i) were also kept fixed at values of $F_i = 1$. The temperature of the primary component was derived from the photometric indices or other sources (see below). The problematic issue of the mass ratio was solved by fixing $q = 1$ because no spectroscopy for most of these selected systems exists, and for detached eclipsing binaries the LC solution is almost insensitive to the photometric mass ratio (see e.g. Terrell & Wilson 2005).

4. METHODS USED FOR THE ANALYSIS

4.1. Apsidal motion analysis

For the analysis, we used the approach as presented below.

1. At the beginning, all of the available photometric data were analysed, resulting in a set of minima times. Preliminary apsidal motion parameters were derived (with the assumption $i = 90^\circ$).
2. Secondly, the eccentricity (e), argument of periastron (ω), and apsidal motion rate ($\dot{\omega}$) that resulted from the apsidal motion analysis were used for the preliminary light curve analysis.
3. As the third step, the inclination (i) from the LC analysis was used for the final apsidal motion analysis.
4. Finally, the resulted e , ω , and $\dot{\omega}$ values from the apsidal motion analysis were used for the final LC analysis.

Moreover, this simple approach was a bit complicated because the minima times were also derived using the light curve template (see the AFP method in Section 4.2). Hence, the LC solution from step 2 allows us to derive the better times of minima for the step 3. The whole process run iteratively until the changes are negligible (usually it was enough to run these four steps two times).

The Opt. Commun. diagrams of all available times of minima were analysed using the method presented by Giménez & García-Pelayo (1983). This is a weighted least-squares iterative procedure, including terms in the eccentricity up to the fifth order. There are five independent variables ($T_0, P_s, e, \dot{\omega}, \omega_0$) determined in this procedure. The periastron position ω is given by the linear equation

$$\omega = \omega_0 + \dot{\omega} E,$$

where $\dot{\omega}$ is the rate of periastron advance, E is the epoch, and the position of periastron for the zero epoch T_0 is denoted as ω_0 . The relation between the sidereal and the anomalistic period, P_s and P_a , is given by

$$P_s = P_a (1 - \dot{\omega}/360^\circ)$$

and the period of apsidal motion by $U = 360^\circ P_a / \dot{\omega}$.

All new precise CCD times of minima were used with a weight of 10 in our computation; some of our less precise measurements were weighted by a factor of five, while the poorly covered minima were given a weight of 1.

4.2. Method of minima fitting

We developed and routinely used a method for deriving the times of minima for selected stars observed during the MACHO and OGLE surveys. This semi-automatic fitting procedure (hereafter AFP) has harvested the fact that the number of data points obtained during these two photometric surveys is large (typically thousands of data points) but obtained during many orbital revolutions of the close pair (a so-called sparse photometry).

Therefore, we can construct the phased light curve of the eclipsing binary in different time epochs. If the apsidal motion is prominent in the system, the shape of the light curve also slightly varies between the different epochs.

The first step is to divide the whole data set of photometry into several different “subsets”, which are used for constructing the individual light curves. Then, we usually choose the data set closest to the half of the time interval covered with observations and use these data points for constructing the light curve to be analysed.

Then, this light curve is analysed using the PHOEBE code, and the theoretical light curve template is being constructed. This LC model is then being used for deriving the individual times of minima easily by fitting this phased light curve to the phased light curves for the individual data sets. The best fit is obtained with the simplex algorithm and the least squares fitting method by only shifting the theoretical and observed light curve in two axis (phase and magnitude). If the star has constant magnitude over the whole time range of our data, there is no need to fit the magnitude shift, and only one free parameter is computed. When we find the best fit, then the times of minima are computed easily according to the ephemerides for a particular data set. Of course,

for eccentric orbit binaries, both primary and secondary minima are being computed separately.

For the input, there are the data points, the time intervals, the ephemerides, and also parameters of the method. These are the duration of eclipse (how large portion of the phase curve around minima is being used for computing), minimum number of data points (if lower, the minimum is not computed), and the depth of minima. If 1/5 of the depth of minima is covered with data points, then this particular minimum is being computed.

Hence, by using this technique, we can usually obtain both primary and secondary minima for each data subset from an original photometry file. Moreover, this method can also be used in these cases, where the minimum is covered only very poorly, or only a descent to the minimum is covered. In these cases, the classical Kwee-van Woerden method would not work properly, so we can obtain more useful data points. On the other hand, we would like to emphasize that the method is suitable only for systems with low eccentricity, where the shape of the light curve is changing only slightly. Otherwise, we have to construct a separate light curve template for each of the data subset.

The whole method is graphically shown in Fig. 1, where an illustrative example of OGLE-SMC-ECL-0720 is being presented. All of the derived times of minima are stored in the online-only Tables 5. There are also given the errors of individual minima times, which are being computed also by AFP in the following way. The set of different solutions was computed for a particular minimum with different parameters of the code (length of interval around each minimum used for the analysis, number of data points according to their precision, etc.), yielding a set of times of minima, which is usually more than 10. From these minima data set, an average and its variance were computed. The variance is then taken as an approximate error estimation for the particular minimum.

5. NOTES ON INDIVIDUAL SYSTEMS

All of the eclipsing systems were analysed using a similar approach, hence we cannot focus on every star in detail. See Table 1 for information and cross-identification of these stars. The abbreviations of the star names were used for all of the systems for a better brevity. That is, OGLE-SMC-ECL-0720 was shortened as #0720, etc. Only the most important results are summarized below. The final light curve fits, and the $O-C$ diagrams are presented in Figs. 2 and 3; the parameters are given in Tables 2 and 3. The whole set of eighteen analysed systems can be divided into a few subsets according to available spectral information.

The largest group in our sample of stars comprise these stars, which were never observed spectroscopically, hence no spectral classification or radial velocity study was published so far. These systems are #0781, #1001, #1298, #1407, #2225, #2251, #2524, and #5233. Most of them were discovered as eclipsing binaries by Udalski et al. (1998), Wyrzykowski et al. (2004), or Faccioli et al. (2007). Several of them were mentioned as eccentric ones with apsidal motion in some of the above mentioned papers. Owing to having no information about their spectra, we only roughly estimated the spectral types from the measurements in photometric filters, as seen in Table

An illustrative example: OGLE-SMC-ECL-0720

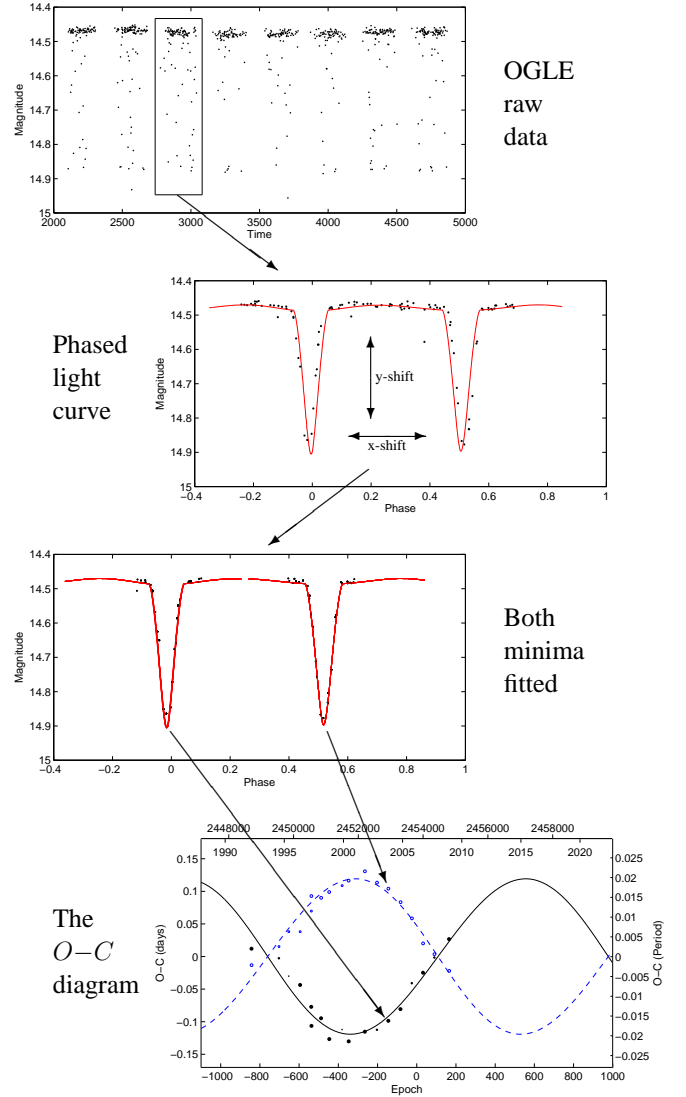


FIG. 1.— How the AFP method works.

1. These observations were usually taken from Massey (2002) and from the dereddened photometric indices the spectral types were estimated (Popper 1980, Ducati et al. 2001, or Cox 2000). For some of the systems, there resulted a non-negligible third light contribution (e.g. #2225, #2251).

For some of the systems, the spectral types were published, so we can use them for a better primary temperature estimation for a subsequent light curve analysis. These systems are #0720, #2534, #3677, #4955, #5422, and #5434 (to this group of stars, two systems #0888 and #3951 also belong, but these were given a special focus in the following subsections). These binaries were also discovered by Udalski et al. (1998) and Faccioli et al. (2007); for some of them, a short note about their apsidal motion was published. The spectral types for these systems given by Evans et al. (2004) and Bonanos et al. (2010) are in good agreement with our spectral types that are estimated from the dereddened photometric indices.

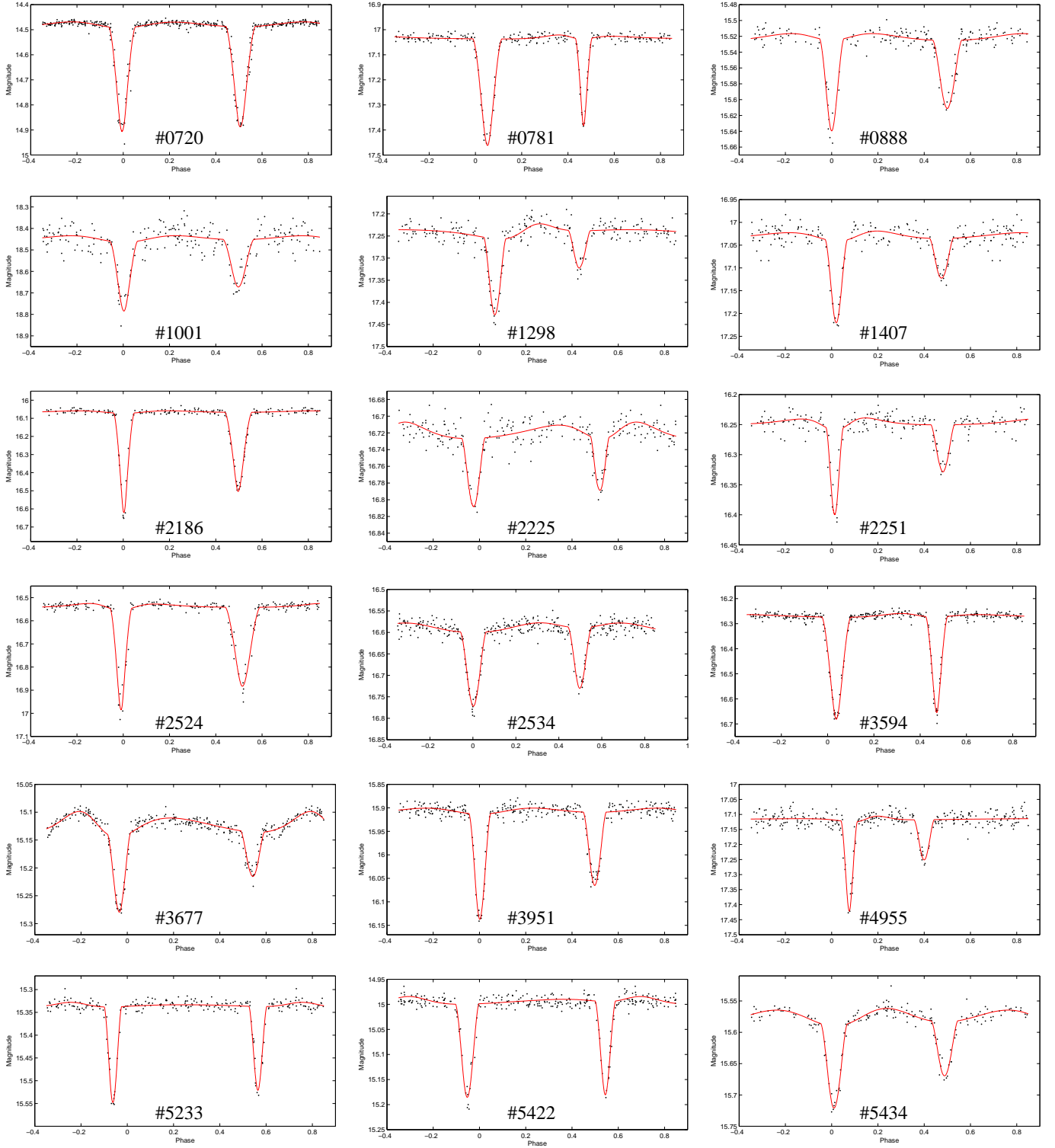


FIG. 2.— Light curves of the analysed systems, the data taken from the OGLE III survey, and the I filter.

TABLE 1
RELEVANT INFORMATION FOR THE ANALYSED SYSTEMS.

System	OGLE II*	MACHO	RA	DE	I_{\max}	$(B - V)$	$(U - B)$	$(B - V)_0$	Sp.type**	Ref.
#0720	SC3 139376	213.15620.12	00 ^h 44 ^m 08 ^s .67	-73°14'18".5	14 ^m 47	-0.16	-0.91	-0.26	B0(IV)	1, 2
#0781	SC3 157218	212.15624.89	00 ^h 44 ^m 39 ^s .73	-72°59'58".5	17 ^m 03	-0.10	-0.78	-0.23	B2	1
#0888	SC4 29231	212.15680.18	00 ^h 45 ^m 30 ^s .72	-73°03'29".7	15 ^m 52	-0.09	-0.82	-0.25	O9V	1, 2
#1001		208.15744.1836	00 ^h 46 ^m 11 ^s .29	-72°35'17".3	18 ^m 44	-0.31	-0.58	-0.12	<i>late B/early A</i>	3
#1298	SC4 163754	212.15848.1258	00 ^h 47 ^m 52 ^s .73	-73°16'34".0	17 ^m 22	-0.04	-0.89	-0.29	B0	1
#1407		208.15861.734	00 ^h 48 ^m 19 ^s .26	-72°21'40".2	17 ^m 02	-0.04	-0.67	-0.21	B3	1
#2186	SC5 311566	208.16083.86	00 ^h 51 ^m 34 ^s .84	-72°45'46".4	16 ^m 06	-0.04	-0.79	-0.25	B0+B0-3	1, 4
#2225	SC6 72782	208.16084.117	00 ^h 51 ^m 41 ^s .80	-72°41'06".1	16 ^m 71	-0.128		-0.22	B3	5, 6
#2251	SC6 61418		00 ^h 51 ^m 46 ^s .64	-72°51'21".7	16 ^m 23	-0.14	-0.91	-0.27	B1	1
#2524	SC6 158178	208.16141.60	00 ^h 52 ^m 42 ^s .32	-72°41'27".9	16 ^m 53	-0.176	-0.86	-0.24	B2	3
#2534		208.16147.22	00 ^h 52 ^m 43 ^s .85	-72°18'08".6	16 ^m 57	-0.04	-0.81	-0.26	B1	1
#3594	SC7 255621	207.16428.1423	00 ^h 57 ^m 26 ^s .41	-72°36'46".2	16 ^m 26	-0.21	-0.72	-0.19	B1+B1-3	1, 4
#3677	SC8 52815	207.16490.6	00 ^h 57 ^m 49 ^s .25	-72°16'55".7	15 ^m 11	-0.16	-0.84	-0.24	B2	1, 7
#3951	SC8 160725		00 ^h 59 ^m 14 ^s .98	-72°11'35".3	15 ^m 90	-0.18	-0.84	-0.24	B1V	8, 9
#4955	SC10 94636	206.16886.52	01 ^h 04 ^m 59 ^s .18	-72°25'29".3	17 ^m 11	-0.16	-0.68	-0.19	B3	1
#5233		206.17061.14	01 ^h 07 ^m 12 ^s .54	-72°11'42".0	15 ^m 34	-0.08	-0.91	-0.28	B0	1
#5422	SC11 111907	206.17170.8	01 ^h 08 ^m 45 ^s .74	-72°31'22".4	14 ^m 99	-0.22	-0.93	-0.26	B1	1
#5434	SC11 118966	206.17173.10	01 ^h 08 ^m 50 ^s .47	-72°17'26".1	15 ^m 56	-0.11	-0.86	-0.26	B1	1

Note: [*] - The full name from OGLE II survey should be OGLE SMC-SCn nnnnnn, [**] - Spectral types given in italics were only estimated from the photometric indices for the first time in the present paper. References: [1] - Massey (2002), [2] - Evans et al. (2004), [3] - Zaritsky et al. (2002), [4] - Hilditch et al. (2005), [5] - Udalski et al. (1998), [6] - Massey et al. (1995), [7] - Bonanos et al. (2010), [8] - Massey et al. (1989), [9] - Massey et al. (2012).

TABLE 2
LIGHT CURVE PARAMETERS FOR THE ANALYSED SYSTEMS.

System	T_1 [K]	T_2 [K]	i [deg]	Ω_1	Ω_2	L_1 [%]	L_2 [%]	L_3 [%]
#0720	31500 (fixed)	31700 (400)	84.57 (0.30)	5.524 (0.061)	7.356 (0.085)	66.87 (0.83)	33.13 (0.68)	0
#0781	23100 (fixed)	16700 (300)	85.08 (0.18)	7.265 (0.086)	8.690 (0.120)	71.90 (1.25)	28.10 (0.98)	0
#0888	33200 (fixed)	38100 (1100)	77.77 (0.38)	6.119 (0.101)	6.128 (0.112)	22.01 (1.85)	26.94 (3.46)	51.05 (4.98)
#1001	11000 (fixed)	9700 (500)	79.13 (0.92)	5.064 (0.204)	6.661 (0.397)	67.48 (1.37)	32.52 (1.02)	0
#1298	30000 (fixed)	19900 (700)	74.68 (0.45)	6.364 (0.138)	6.701 (0.174)	70.46 (1.32)	29.54 (0.77)	0
#1407	19000 (fixed)	19100 (700)	75.60 (0.50)	5.907 (0.147)	6.833 (0.177)	56.26 (1.06)	39.10 (1.00)	4.64 (1.87)
#2186	30100 (fixed)	28500 (300)	87.02 (0.22)	6.843 (0.058)	8.040 (0.097)	62.73 (3.14)	36.00 (1.25)	4.03 (2.59)
#2225	11600 (fixed)	7100 (200)	80.33 (0.53)	5.678 (0.100)	11.334 (0.490)	60.98 (2.87)	4.58 (0.57)	34.45 (1.55)
#2251	26200 (fixed)	30600 (900)	79.62 (0.26)	6.149 (0.080)	10.184 (0.184)	48.35 (3.02)	17.91 (1.26)	33.73 (4.05)
#2524	23100 (fixed)	24600 (600)	83.32 (0.37)	6.128 (0.085)	7.165 (0.112)	56.63 (1.26)	41.53 (2.03)	1.85 (5.76)
#2534	26200 (fixed)	18300 (300)	76.23 (0.28)	5.690 (0.050)	6.150 (0.052)	61.67 (1.79)	28.64 (1.58)	9.69 (2.63)
#3594	25500 (fixed)	22000 (200)	83.60 (0.41)	7.095 (0.040)	6.668 (0.055)	50.50 (1.56)	48.00 (1.03)	1.49 (1.96)
#3677	23100 (fixed)	25100 (300)	73.60 (0.22)	5.029 (0.029)	7.833 (0.064)	74.51 (1.07)	25.49 (0.94)	0
#3951	26200 (fixed)	24400 (200)	78.50 (0.24)	6.699 (0.055)	6.789 (0.056)	53.76 (0.97)	46.24 (1.16)	0
#4955	19000 (fixed)	17400 (500)	80.01 (0.31)	7.868 (0.165)	8.591 (0.180)	58.97 (0.75)	41.03 (0.79)	0
#5233	30000 (fixed)	29400 (300)	80.52 (0.21)	8.762 (0.098)	7.843 (0.093)	44.09 (1.02)	55.91 (0.93)	0
#5422	26200 (fixed)	20400 (300)	79.18 (0.33)	7.076 (0.098)	7.070 (0.102)	54.69 (2.34)	36.51 (4.57)	8.80 (7.82)
#5434	26200 (fixed)	24200 (400)	71.72 (0.40)	5.400 (0.061)	5.516 (0.059)	53.49 (1.14)	43.86 (1.62)	2.65 (2.01)

TABLE 3
THE PARAMETERS OF THE APSIDAL MOTION FOR THE INDIVIDUAL SYSTEMS.

System	$T_0 - 2400000$ [HJD]	P_s [days]	e	$\dot{\omega}$ [deg/cycle]	ω_0 [deg]	U [yr]
#0720	53803.390 (21)	6.052322 (48)	0.062 (16)	0.2070 (300)	67.6 (5.0)	28.8 (5.5)
#0781	52745.417 (32)	3.299923 (48)	0.310 (75)	0.0301 (37)	244.4 (10.3)	108.1 (15.1)
#0888	53470.954 (15)	1.918337 (11)	0.143 (34)	0.0474 (193)	89.3 (4.7)	39.9 (11.6)
#1001	53090.7643 (35)	1.1621122 (18)	0.072 (14)	0.0601 (69)	94.5 (7.8)	19.0 (2.4)
#1298	53501.194 (14)	1.7532121 (99)	0.219 (42)	0.0677 (93)	130.0 (4.2)	25.5 (4.1)
#1407	53470.497 (13)	2.100755 (11)	0.151 (47)	0.0427 (120)	115.9 (3.9)	46.3 (18.0)
#2186	53470.314 (15)	3.291316 (20)	0.227 (82)	0.0258 (42)	91.9 (2.6)	125.7 (24.5)
#2225	53089.914 (10)	1.491721 (8)	0.187 (48)	0.0351 (121)	291.9 (8.8)	41.9 (21.8)
#2251	54179.695 (25)	2.336038 (33)	0.271 (22)	0.0484 (132)	99.8 (5.6)	47.6 (17.8)
#2524	53471.664 (24)	2.169236 (23)	0.263 (68)	0.0475 (92)	81.5 (6.5)	45.0 (10.8)
#2534	53277.1246 (72)	2.2967384 (72)	0.078 (24)	0.0357 (57)	265.0 (3.4)	63.3 (11.9)
#3594	53280.315 (41)	4.330333 (80)	0.194 (69)	0.0300 (63)	238.1 (9.9)	142.1 (38.9)
#3677	53278.036 (52)	5.241539 (117)	0.153 (55)	0.0554 (133)	40.2 (4.6)	93.3 (33.6)
#3951	53277.2672 (75)	3.104291 (17)	0.092 (20)	0.0476 (165)	92.9 (4.0)	64.3 (33.9)
#4955	54022.771 (52)	2.772183 (53)	0.338 (48)	0.0239 (84)	143.3 (5.0)	114.4 (51.5)
#5233	52746.459 (45)	5.068362 (103)	0.199 (57)	0.1915 (321)	7.0 (8.7)	26.1 (5.2)
#5422	53656.966 (26)	3.040295 (31)	0.199 (56)	0.0301 (83)	318.1 (6.0)	99.4 (37.9)
#5434	53478.7191 (72)	2.886936 (9)	0.051 (16)	0.0747 (214)	129.6 (3.4)	38.1 (15.2)

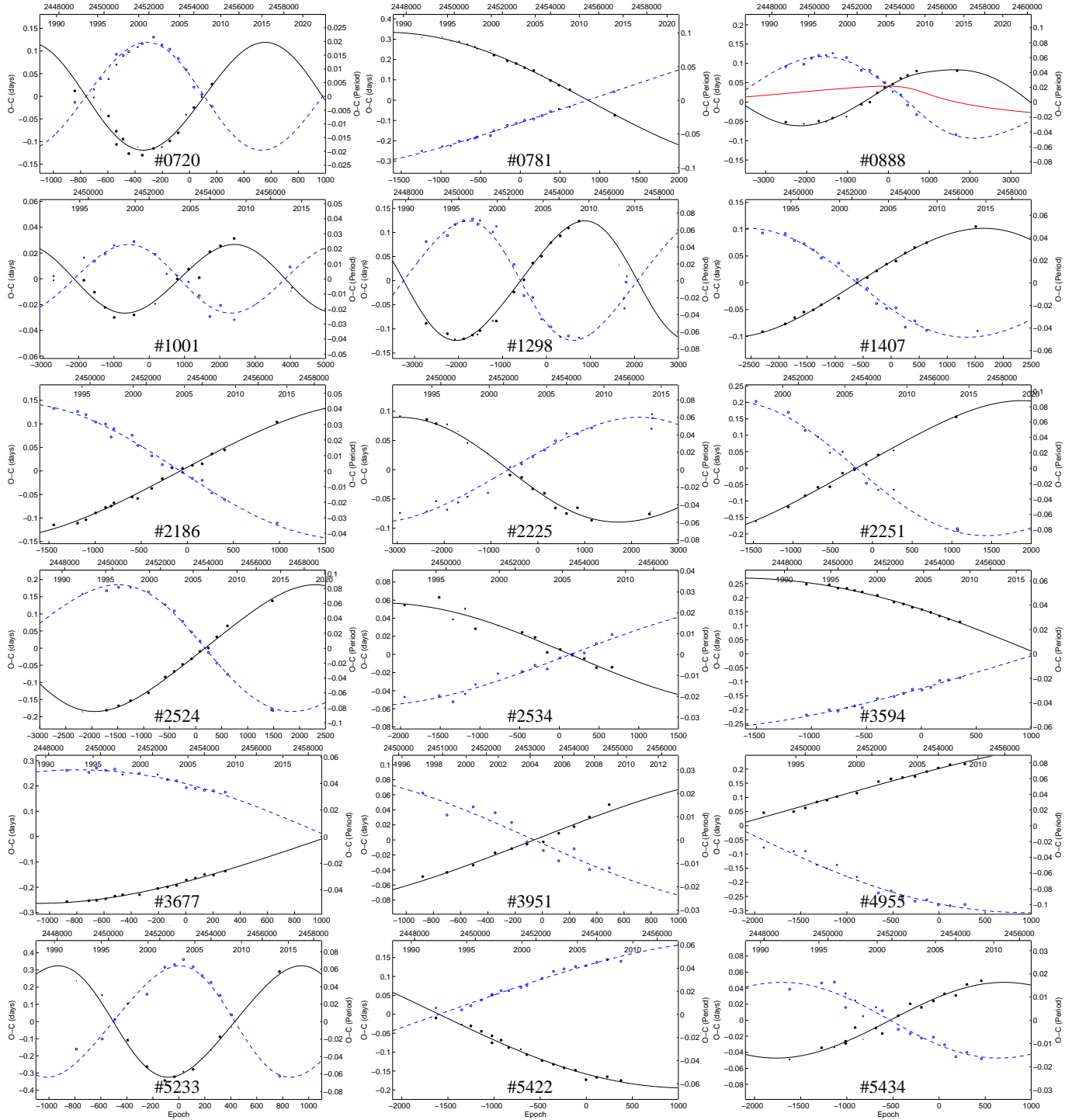


FIG. 3.— Opt. Commun. diagram for the times of minima for the analysed systems. The continuous and dashed curves represent predictions for the primary and secondary eclipses, respectively. The individual primary and secondary minima are denoted by dots and open circles, respectively. Larger symbols correspond to the measurements, which were given higher weights.

5.1. OGLE-SMC-ECL-2186

Two systems, #2186 and #3594, were even published with their light and radial velocity curves solutions. The first one (#2186) was analysed by Wyrthe & Wilson (2001), who presented a preliminary light curve solution with an eccentric orbit with $e = 0.068$. Graczyk (2003) analysed the LC of #2186, yielding an eccentricity of 0.251, no third light, and the luminosity ratio of $L_2/L_1 = 0.843$. Wyrzykowski et al. (2004) presented a note about its apsidal motion but with no estimation of

its period. Concerning the spectral type, Graczyk (2003) estimated the types of about O9V+O9V but dealt only with the photometry. Later, Hilditch et al. (2005) published its spectral type to be B0+B0-3 based on 15 spectra of the star. They also analysed the light curve, yielding a value of the eccentricity of the orbit to be 0.063. However, their LC solution is not very convincing due to poor fit of the secondary minimum.

5.2. OGLE-SMC-ECL-3594

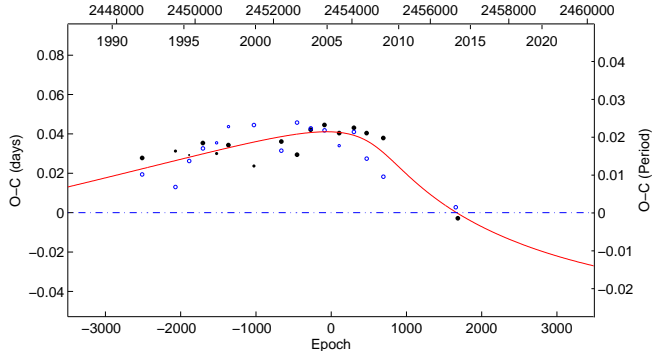


FIG. 4.— Opt. Commun. diagram of #0888 after subtraction of the apsidal motion term.

The second system (#3594) was also studied by Wytke & Wilson (2001), who included this star into their sample of SMC eclipsing binaries with the light curve solution, which result in orbital inclination of 88.9° and an eccentricity of 0.144. Hilditch et al. (2005) analysed the system in more detail, resulting in an orbital eccentricity of 0.19 (based on photometry and spectroscopy together) and the spectral types of both components as B1+B1-3.

5.3. OGLE-SMC-ECL-0888

The object #0888 was first mentioned by Wyrzykowski et al. (2004), who also noted about its apsidal motion. Its spectral type was derived to be about O9V by Evans et al. (2004). We found that the pure apsidal motion is not able to describe the $O - C$ diagram in detail, hence another effect has also to be included. We also tried to fit the parabolic fit to the ephemerides, with the apsidal motion hypothesis (can be interpreted as a mass transfer between the components, despite improbable for detached binary). However, this fit was also not very satisfactory. Therefore, we used a different code that computes the apsidal motion parameters with the third-body orbit (a so-called ‘light travel time’ effect), as seen in for example Irwin (1959) or Mayer (1990). Ten parameters were fitted (five from the apsidal motion, five from the third body hypothesis); thus, this approach led to an acceptable solution with the lowest sum of squares residuals. The final parameters of the fit are given in Tables 3 and 4; the complete Opt. Commun. diagrams are shown in Figs. 3 and 4.

From the third-body parameters, we could also compute the mass function of the distant component, which resulted in $f(m_3) = 0.059 \pm 0.015 M_\odot$. From this value, one can calculate a predicted minimal mass of the third body (i.e. assuming coplanar orbits $i_3 = 90^\circ$), which re-

TABLE 4
THIRD BODY ORBIT PARAMETERS FOR #0888.

Parameter [Unit]	Value
p_3 [yr]	72.1 ± 28.0
A_3 [day]	0.030 ± 0.011
T_3 [HJD]	2454900 ± 8700
e_3	0.709 ± 0.247
ω_3 [deg]	154.0 ± 15.6

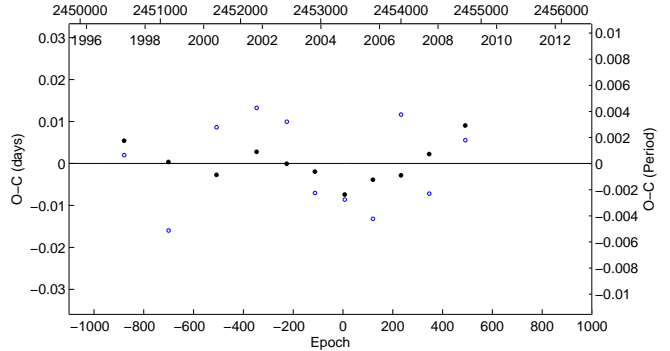


FIG. 5.— Opt. Commun. diagram of #3951 after subtraction of the apsidal motion term.

sulted in $m_{3,min} = 4.9 M_\odot$. If we propose such a body in the system, one can ask whether it is detectable somehow in the already obtained data. The period is long for continuous monitoring of the radial velocity changes, but detecting the third light in the light curve solution would be promising. Assuming a normal main sequence star, its luminosity would be of about only $L_{3,min} = 1 - 2\%$ of the total system luminosity. Such a weak third light would be hardly detectable in our poor-quality photometric data, but it is worth of try. Hence, we performed a new light curve solution with a special focus on the value of the third light for a LC solution. The value was really obtained, and its value is not negligible at all. As one can see from the parameters presented in Table 2, the third light represents about one half of the total light. This finding naturally explains why both the eclipses are so shallow. On the other hand, one can ask to which body the estimated spectral type of O9V belongs. If the third body is the dominant source, this is probably the O9V component, but the primary temperature of 33200 K was assumed using the O9V primary, which now seems to be incorrect. However, having no other relevant information about the individual spectral types, one cannot easily assume a different primary temperature. Thus, we can conclude that the third body is probably present and orbits around the EB pair on orbit which is mildly inclined from the originally assumed 90° . It is hard to say anything more about such a body because of the high errors of the parameters (period, third light, etc.). More precise photometry or radial velocities would be very welcome for a final confirmation of our hypothesis.

5.4. OGLE-SMC-ECL-3951

The object #3951 is a part of the SMC open cluster NGC 346. Its eclipsing nature and orbital period was first presented by Udalski et al. (1998). Later, the star was classified as B1V by Massey et al. (2012). From the period analysis, a weak quasi-periodic signal also on the residuals after subtraction of the apsidal motion hypothesis (see Fig. 5) resulted. However, the variation is still too spurious for any final confirmation yet and we have not even try to fit the data with any additional variation, as in the previous case.

6. DISCUSSION AND CONCLUSIONS

Our study provides the parameters of the apsidal motion for eighteen early-type binary systems located in the SMC. For most of the binaries, this is the first attempt

to estimate the apsidal motion rates, and the light curve solution. In our own Galaxy there are a few hundreds of apsidal motion eclipsing binaries known; however, in other galaxies their number is still very limited. Hence this study still presents an important contribution to the topic. However, for only three systems from our sample (#1001, #1298, and #5233), the apsidal motion was derived from adequately large data set covering almost one apsidal period. The relativistic effects for the selected systems are weak, being up to 10 % of the total apsidal motion rate. For the system #0888, the third body hypothesis was also presented and discussed.

The apsidal motion in EEBs has been used for decades to test evolutionary stellar models. Thus, one can ask whether our results can be used for deriving the internal structure constants for these stars in SMC. However, dealing with no radial velocities for most of the systems and with rather poor data coverage during the apsidal motion period, the parameters are too uncertain and affected by large errors. For these systems where the apsidal period is well-covered, a detailed spectroscopic analysis is missing, and vice versa, for systems where the radial velocity study was performed, the apsidal period has yet to be only poorly covered with data. However, for any testing of the stellar structure models or for the general relativity tests, the quality of the input data has to be an order of magnitude better (which implies long-

term collection of the observations and data that covers the whole apsidal period in the following decades). Some of the systems are bright enough for a spectral monitoring, hence we encourage the observers to obtain new, high-dispersion, and high-S/N spectroscopic observations. With such data, methods, like spectral disentangling, can help us construct the radial velocity curves of both components, confirm the apsidal motion hypothesis, test the stellar structure models, or detect the third bodies, as indicated from our analysis.

We do thank the MACHO and OGLE teams for making all of the observations easily public available. This work was supported by the Czech Science Foundation grant no. P209/10/0715, by the grant UNCE 12 of the Charles University in Prague, and by the grant LG12001 of the Ministry of Education of the Czech Republic. We are also grateful to the ESO team at the La Silla Observatory for their help in maintaining and operating the Danish telescope. The following internet-based resources were used in research for this paper: the SIMBAD database and the VizieR service operated at the CDS, Strasbourg, France, and the NASA's Astrophysics Data System Bibliographic Services.

REFERENCES

- Bonanos, A. Z., Lennon, D. J., Köhlinger, F., et al. 2010, *AJ*, 140, 416
 Claret, A. 2005, *A&A*, 440, 647
 Cox, A. N. 2000, in *Allen's Astrophysical Quantities*, 4th ed., ed. Arthur N. Cox (Springer Verlag, New York)
 Ducati, J. R., Bevilacqua, C. M., Rembold, S. B., & Ribeiro, D. 2001, *ApJ*, 558, 309
 Evans, C. J., Howarth, I. D., Irwin, M. J., Burnley, A. W., & Harries, T. J. 2004, *MNRAS*, 353, 601
 Faccioli, L., Alcock, C., Cook, K. et al. 2007, *AJ*, 134, 1963
 Giménez, A. 1994, *Experimental Astronomy*, 5, 91
 Giménez, A., & García-Pelayo, J.M. 1983, *Ap&SS*, 92, 203
 Graczyk, D. 2003, *MNRAS*, 342, 1334
 Graczyk, D., Soszyński, I., Poleski, R., et al. 2011, *AcA*, 61, 103
 Hilditch, R. W., Howarth, I. D., & Harries, T. J. 2005, *MNRAS*, 357, 304
 Irwin, J. B. 1959, *AJ*, 64, 149
 Kwee, K.K., & van Woerden, H. 1956, *Bull. Astron. Inst. Netherlands*, 12, 327
 Maeder, A. 1999, *A&A*, 347, 185
 Massey, P., Parker, J. W., & Garmany, C. D. 1989, *AJ*, 98, 1305
 Massey, P., Lang, C. C., Degioia-Eastwood, K., & Garmany, C. D. 1995, *ApJ*, 438, 188
 Massey, P. 2002, *ApJS*, 141, 81
 Massey, P., Morrell, N. I., Neugent, K. F., et al. 2012, *ApJ*, 748, 96
 Mayer, P. 1990, *BAICz*, 41, 231
 Michalska, G. 2007, *IBVS* No. 5759
 Michalska, G. & Pigulski, A. 2005, *A&A*, 434, 89
 North, P., Gauderon, R., Barblan, F., & Royer, F. 2010, *A&A*, 520, A74
 Pawlak, M., Graczyk, D., Soszyński, I., et al. 2013, *AcA*, 63, 323
 Popper, D. M. 1980, *ARA&A*, 18, 115
 Prša, A., & Zwitter, T. 2005, *ApJ*, 628, 426
 Ribas, I. 2004, *New Astronomy Reviews*, 48, 731
 Terrell, D., & Wilson, R. E. 2005, *Ap&SS*, 296, 221
 Udalski, A., Soszynski, I., Szymanski, M., et al. 1998, *AcA*, 48, 563
 van Hamme, W. 1993, *AJ*, 106, 2096
 Wilson, R. E., & Devinney, E. J. 1971, *ApJ*, 166, 605
 Wyrzykowski, L., Udalski, A., Kubiak, M., et al. 2004, *AcA*, 54, 1
 Wyithe, J. S. B., & Wilson, R. E. 2001, *ApJ*, 559, 260
 Zaritsky, D., Harris, J., Thompson, I. B., Grebel, E. K., & Massey, P. 2002, *AJ*, 123, 855
 Zasche, P. & Wolf, M. 2013, *A&A*, 558, 51

APPENDIX

TABLES OF MINIMA

TABLE 5
LIST OF THE MINIMA TIMINGS USED FOR THE ANALYSIS.

Star	JD Hel.- 2400000	Error [day]	Type	Filter	Source / Observatory
OGLE-SMC-ECL-0720	48701.29443	0.00741	Prim	B+R	MACHO
OGLE-SMC-ECL-0720	48704.29533	0.00922	Sec	B+R	MACHO
OGLE-SMC-ECL-0720	49548.60490	0.01197	Prim	B+R	MACHO
OGLE-SMC-ECL-0720	49551.64897	0.01236	Sec	B+R	MACHO
OGLE-SMC-ECL-0720	49851.19352	0.01915	Prim	B+R	MACHO
OGLE-SMC-ECL-0720	49854.28789	0.02131	Sec	B+R	MACHO
OGLE-SMC-ECL-0720	50202.21473	0.00924	Prim	B+R	MACHO
OGLE-SMC-ECL-0720	50205.32260	0.02286	Sec	B+R	MACHO
OGLE-SMC-ECL-0720	50547.16343	0.00657	Prim	B+R	MACHO
OGLE-SMC-ECL-0720	50550.33647	0.01600	Sec	B+R	MACHO
OGLE-SMC-ECL-0720	50849.76208	0.00929	Prim	B+R	MACHO
OGLE-SMC-ECL-0720	50852.97305	0.00908	Sec	B+R	MACHO
OGLE-SMC-ECL-0720	51497.34320	0.01915	Prim	B+R	MACHO
OGLE-SMC-ECL-0720	51500.59013	0.01798	Sec	B+R	MACHO
OGLE-SMC-ECL-0720	50550.35962	0.00592	Sec	I	OGLE II
OGLE-SMC-ECL-0720	50553.18661	0.00439	Prim	I	OGLE II
OGLE-SMC-ECL-0720	51101.12700	0.00486	Sec	I	OGLE II
OGLE-SMC-ECL-0720	51103.92761	0.00022	Prim	I	OGLE II
OGLE-SMC-ECL-0720	51700.32442	0.00002	Sec	I	OGLE II
OGLE-SMC-ECL-0720	51703.10399	0.00089	Prim	I	OGLE II
OGLE-SMC-ECL-0720	52199.40921	0.00391	Prim	I	OGLE III
OGLE-SMC-ECL-0720	52202.68144	0.00649	Sec	I	OGLE III
OGLE-SMC-ECL-0720	52574.65616	0.01128	Prim	I	OGLE III
OGLE-SMC-ECL-0720	52577.90814	0.00526	Sec	I	OGLE III
OGLE-SMC-ECL-0720	52925.70455	0.00698	Prim	I	OGLE III
OGLE-SMC-ECL-0720	52928.93350	0.00340	Sec	I	OGLE III
OGLE-SMC-ECL-0720	53300.96643	0.00535	Prim	I	OGLE III
OGLE-SMC-ECL-0720	53304.15675	0.00206	Sec	I	OGLE III
OGLE-SMC-ECL-0720	53652.04092	0.01013	Prim	I	OGLE III
OGLE-SMC-ECL-0720	53655.16657	0.00666	Sec	I	OGLE III
OGLE-SMC-ECL-0720	53997.03938	0.00490	Prim	I	OGLE III
OGLE-SMC-ECL-0720	54000.11047	0.00739	Sec	I	OGLE III
OGLE-SMC-ECL-0720	54348.09727	0.01183	Prim	I	OGLE III
OGLE-SMC-ECL-0720	54351.12853	0.00173	Sec	I	OGLE III
OGLE-SMC-ECL-0720	54802.04975	0.00811	Prim	I	OGLE III
OGLE-SMC-ECL-0720	54805.02717	0.00004	Sec	I	OGLE III
OGLE-SMC-ECL-0781	48650.52017	0.00589	Prim	B+R	MACHO
OGLE-SMC-ECL-0781	48651.61198	0.00601	Sec	B+R	MACHO
OGLE-SMC-ECL-0781	49498.60339	0.00758	Prim	B+R	MACHO
OGLE-SMC-ECL-0781	49499.71447	0.00766	Sec	B+R	MACHO
OGLE-SMC-ECL-0781	49851.67410	0.00639	Prim	B+R	MACHO
OGLE-SMC-ECL-0781	49852.80913	0.00995	Sec	B+R	MACHO
OGLE-SMC-ECL-0781	50201.46365	0.00429	Prim	B+R	MACHO
OGLE-SMC-ECL-0781	50202.62334	0.00207	Sec	B+R	MACHO
OGLE-SMC-ECL-0781	50551.24174	0.00636	Prim	B+R	MACHO
OGLE-SMC-ECL-0781	50552.42087	0.00430	Sec	B+R	MACHO
OGLE-SMC-ECL-0781	50851.52298	0.00449	Prim	B+R	MACHO
OGLE-SMC-ECL-0781	50852.72368	0.00320	Sec	B+R	MACHO
OGLE-SMC-ECL-0781	51501.59099	0.00867	Prim	B+R	MACHO
OGLE-SMC-ECL-0781	51502.82123	0.00378	Sec	B+R	MACHO
OGLE-SMC-ECL-0781	50950.51118	0.00632	Prim	I	OGLE II
OGLE-SMC-ECL-0781	50951.72688	0.00346	Sec	I	OGLE II
OGLE-SMC-ECL-0781	51650.06399	0.00269	Prim	I	OGLE II
OGLE-SMC-ECL-0781	51651.34170	0.00330	Sec	I	OGLE II
OGLE-SMC-ECL-0781	52201.12370	0.00245	Prim	I	OGLE III
OGLE-SMC-ECL-0781	52202.45512	0.00330	Sec	I	OGLE III
OGLE-SMC-ECL-0781	52574.00067	0.00203	Prim	I	OGLE III
OGLE-SMC-ECL-0781	52575.35665	0.00219	Sec	I	OGLE III
OGLE-SMC-ECL-0781	52923.77283	0.00191	Prim	I	OGLE III
OGLE-SMC-ECL-0781	52925.16354	0.00283	Sec	I	OGLE III
OGLE-SMC-ECL-0781	53299.94961	0.00223	Prim	I	OGLE III
OGLE-SMC-ECL-0781	53301.36089	0.00390	Sec	I	OGLE III
OGLE-SMC-ECL-0781	53649.71827	0.00569	Prim	I	OGLE III
OGLE-SMC-ECL-0781	53651.16977	0.00287	Sec	I	OGLE III
OGLE-SMC-ECL-0781	53999.48473	0.00358	Prim	I	OGLE III
OGLE-SMC-ECL-0781	54000.98147	0.00319	Sec	I	OGLE III
OGLE-SMC-ECL-0781	54349.25336	0.00150	Prim	I	OGLE III
OGLE-SMC-ECL-0781	54350.78606	0.00575	Sec	I	OGLE III
OGLE-SMC-ECL-0781	54801.32027	0.00152	Prim	I	OGLE III
OGLE-SMC-ECL-0781	54802.88593	0.00470	Sec	I	OGLE III
OGLE-SMC-ECL-0781	56637.71770	0.00052	Sec	R	DK154
OGLE-SMC-ECL-0781	56675.55172	0.00225	Prim	R	DK154
OGLE-SMC-ECL-0888	48650.12114	0.00495	Prim	B+R	MACHO
OGLE-SMC-ECL-0888	48651.22335	0.00508	Sec	B+R	MACHO
OGLE-SMC-ECL-0888	49499.94006	0.00870	Prim	B+R	MACHO
OGLE-SMC-ECL-0888	49501.05324	0.00649	Sec	B+R	MACHO
OGLE-SMC-ECL-0888	49849.07573	0.01044	Prim	B+R	MACHO
OGLE-SMC-ECL-0888	49850.20619	0.00930	Sec	B+R	MACHO
OGLE-SMC-ECL-0888	50200.13984	0.00504	Prim	B+R	MACHO
OGLE-SMC-ECL-0888	50201.26861	0.00575	Sec	B+R	MACHO
OGLE-SMC-ECL-0888	50549.27599	0.00811	Prim	B+R	MACHO

TABLE 6
LIST OF THE MINIMA TIMINGS USED FOR THE ANALYSIS.

Star	JD Hel.- 2400000	Error [day]	Type	Filter	Source / Observatory
OGLE-SMC-ECL-0888	50550.40710	0.01648	Sec	B+R	MACHO
OGLE-SMC-ECL-0888	50850.46408	0.00330	Prim	B+R	MACHO
OGLE-SMC-ECL-0888	50851.59112	0.01159	Sec	B+R	MACHO
OGLE-SMC-ECL-0888	51500.78388	0.00681	Prim	B+R	MACHO
OGLE-SMC-ECL-0888	51501.89603	0.00505	Sec	B+R	MACHO
OGLE-SMC-ECL-0888	52199.09028	0.00528	Prim	I	OGLE III
OGLE-SMC-ECL-0888	52200.13742	0.00884	Sec	I	OGLE III
OGLE-SMC-ECL-0888	52600.02846	0.00631	Prim	I	OGLE III
OGLE-SMC-ECL-0888	52601.06977	0.00736	Sec	I	OGLE III
OGLE-SMC-ECL-0888	52949.18978	0.00333	Prim	I	OGLE III
OGLE-SMC-ECL-0888	52950.19052	0.00191	Sec	I	OGLE III
OGLE-SMC-ECL-0888	53300.25949	0.00116	Prim	I	OGLE III
OGLE-SMC-ECL-0888	53301.23084	0.00399	Sec	I	OGLE III
OGLE-SMC-ECL-0888	53674.34361	0.00409	Prim	I	OGLE III
OGLE-SMC-ECL-0888	53675.28319	0.01150	Sec	I	OGLE III
OGLE-SMC-ECL-0888	54050.35279	0.00313	Prim	I	OGLE III
OGLE-SMC-ECL-0888	54051.26885	0.00038	Sec	I	OGLE III
OGLE-SMC-ECL-0888	54374.55955	0.00380	Prim	I	OGLE III
OGLE-SMC-ECL-0888	54375.44152	0.00309	Sec	I	OGLE III
OGLE-SMC-ECL-0888	54800.44108	0.00414	Prim	I	OGLE III
OGLE-SMC-ECL-0888	54801.28789	0.00905	Sec	I	OGLE III
OGLE-SMC-ECL-0888	56648.59424	0.00055	Sec	R	DK154
OGLE-SMC-ECL-0888	56699.59546	0.00175	Prim	R	DK154
OGLE-SMC-ECL-1001	48850.21555	0.00273	Prim	B+R	MACHO
OGLE-SMC-ECL-1001	48850.79998	0.00609	Sec	B+R	MACHO
OGLE-SMC-ECL-1001	49849.63212	0.00151	Prim	B+R	MACHO
OGLE-SMC-ECL-1001	49850.23064	0.00839	Sec	B+R	MACHO
OGLE-SMC-ECL-1001	50199.41863	0.00345	Prim	B+R	MACHO
OGLE-SMC-ECL-1001	50200.02376	0.00438	Sec	B+R	MACHO
OGLE-SMC-ECL-1001	50550.36477	0.00404	Prim	B+R	MACHO
OGLE-SMC-ECL-1001	50550.98731	0.00361	Sec	B+R	MACHO
OGLE-SMC-ECL-1001	50850.18196	0.00182	Prim	B+R	MACHO
OGLE-SMC-ECL-1001	50850.81887	0.00465	Sec	B+R	MACHO
OGLE-SMC-ECL-1001	51499.80461	0.00227	Prim	B+R	MACHO
OGLE-SMC-ECL-1001	51500.44253	0.00341	Sec	B+R	MACHO
OGLE-SMC-ECL-1001	52199.40475	0.00254	Prim	I	OGLE III
OGLE-SMC-ECL-1001	52200.02416	0.00093	Sec	I	OGLE III
OGLE-SMC-ECL-1001	52199.40475	0.00254	Prim	I	OGLE III
OGLE-SMC-ECL-1001	52575.37135	0.00282	Sec	I	OGLE III
OGLE-SMC-ECL-1001	52924.58209	0.00070	Prim	I	OGLE III
OGLE-SMC-ECL-1001	52925.16579	0.00325	Sec	I	OGLE III
OGLE-SMC-ECL-1001	53299.95187	0.00042	Prim	I	OGLE III
OGLE-SMC-ECL-1001	53300.52307	0.00219	Sec	I	OGLE III
OGLE-SMC-ECL-1001	53649.74110	0.00006	Prim	I	OGLE III
OGLE-SMC-ECL-1001	53650.30821	0.00044	Sec	I	OGLE III
OGLE-SMC-ECL-1001	53999.55700	0.00150	Prim	I	OGLE III
OGLE-SMC-ECL-1001	54000.08782	0.00011	Sec	I	OGLE III
OGLE-SMC-ECL-1001	54350.51940	0.00014	Prim	I	OGLE III
OGLE-SMC-ECL-1001	54351.05432	0.00070	Sec	I	OGLE III
OGLE-SMC-ECL-1001	54800.26261	0.00178	Prim	I	OGLE III
OGLE-SMC-ECL-1001	54800.78059	0.00223	Sec	I	OGLE III
OGLE-SMC-ECL-1001	56641.60734	0.00122	Sec	R	DK154
OGLE-SMC-ECL-1001	56673.54658	0.00453	Prim	R	DK154
OGLE-SMC-ECL-1001	56702.60206	0.00200	Prim	R	DK154
OGLE-SMC-ECL-1298	48700.80975	0.00568	Prim	B+R	MACHO
OGLE-SMC-ECL-1298	48701.85571	0.00730	Sec	B+R	MACHO
OGLE-SMC-ECL-1298	49549.34310	0.00605	Prim	B+R	MACHO
OGLE-SMC-ECL-1298	49550.42315	0.00753	Sec	B+R	MACHO
OGLE-SMC-ECL-1298	49849.13107	0.01288	Prim	B+R	MACHO
OGLE-SMC-ECL-1298	49850.24535	0.00998	Sec	B+R	MACHO
OGLE-SMC-ECL-1298	50199.77445	0.00300	Prim	B+R	MACHO
OGLE-SMC-ECL-1298	50200.89616	0.00724	Sec	B+R	MACHO
OGLE-SMC-ECL-1298	50550.42479	0.00531	Prim	B+R	MACHO
OGLE-SMC-ECL-1298	50551.54191	0.00447	Sec	B+R	MACHO
OGLE-SMC-ECL-1298	50850.23337	0.00688	Prim	B+R	MACHO
OGLE-SMC-ECL-1298	50851.33824	0.01225	Sec	B+R	MACHO
OGLE-SMC-ECL-1298	51500.69514	0.00657	Prim	B+R	MACHO
OGLE-SMC-ECL-1298	51501.76815	0.01206	Sec	B+R	MACHO
OGLE-SMC-ECL-1298	50749.64318	0.00432	Sec	I	OGLE II
OGLE-SMC-ECL-1298	50750.29216	0.00168	Prim	I	OGLE II
OGLE-SMC-ECL-1298	51360.43853	0.00065	Prim	I	OGLE II
OGLE-SMC-ECL-1298	51361.49925	0.01471	Sec	I	OGLE II
OGLE-SMC-ECL-1298	52200.28714	0.00109	Prim	I	OGLE III
OGLE-SMC-ECL-1298	52201.22077	0.00300	Sec	I	OGLE III
OGLE-SMC-ECL-1298	52600.04481	0.00253	Prim	I	OGLE III
OGLE-SMC-ECL-1298	52600.88875	0.00701	Sec	I	OGLE III
OGLE-SMC-ECL-1298	52950.72224	0.00129	Prim	I	OGLE III
OGLE-SMC-ECL-1298	52951.52767	0.00227	Sec	I	OGLE III
OGLE-SMC-ECL-1298	53299.62553	0.00384	Prim	I	OGLE III
OGLE-SMC-ECL-1298	53300.37165	0.03122	Sec	I	OGLE III
OGLE-SMC-ECL-1298	53674.84148	0.00361	Prim	I	OGLE III

TABLE 7
LIST OF THE MINIMA TIMINGS USED FOR THE ANALYSIS.

Star	JD Hel.- 2400000	Error [day]	Type	Filter	Source / Observatory
OGLE-SMC-ECL-1298	53675.54332	0.00274	Sec	I	OGLE III
OGLE-SMC-ECL-1298	54050.04304	0.00084	Prim	I	OGLE III
OGLE-SMC-ECL-1298	54050.71048	0.08333	Sec	I	OGLE III
OGLE-SMC-ECL-1298	54374.40371	0.00178	Prim	I	OGLE III
OGLE-SMC-ECL-1298	54375.05651	0.00324	Sec	I	OGLE III
OGLE-SMC-ECL-1298	54800.44849	0.00472	Prim	I	OGLE III
OGLE-SMC-ECL-1298	54801.08349	0.09458	Sec	I	OGLE III
OGLE-SMC-ECL-1298	56397.53405	0.00545	Prim	R	DK154
OGLE-SMC-ECL-1298	56580.67593	0.01310	Sec	R	DK154
OGLE-SMC-ECL-1298	56608.70669	0.00287	Sec	R	DK154
OGLE-SMC-ECL-1298	56673.62977	0.00118	Sec	R	DK154
OGLE-SMC-ECL-1298	56702.56995	0.00786	Prim	R	DK154
OGLE-SMC-ECL-1407	48649.17421	0.00323	Prim	B+R	MACHO
OGLE-SMC-ECL-1407	48650.40889	0.00669	Sec	B+R	MACHO
OGLE-SMC-ECL-1407	49499.99436	0.00697	Prim	B+R	MACHO
OGLE-SMC-ECL-1407	49501.21343	0.00811	Sec	B+R	MACHO
OGLE-SMC-ECL-1407	49850.83227	0.00611	Prim	B+R	MACHO
OGLE-SMC-ECL-1407	49852.02643	0.00710	Sec	B+R	MACHO
OGLE-SMC-ECL-1407	50199.56787	0.01047	Prim	B+R	MACHO
OGLE-SMC-ECL-1407	50200.74580	0.00719	Sec	B+R	MACHO
OGLE-SMC-ECL-1407	50550.39800	0.00301	Prim	B+R	MACHO
OGLE-SMC-ECL-1407	50551.56030	0.00742	Sec	B+R	MACHO
OGLE-SMC-ECL-1407	50850.81538	0.00361	Prim	B+R	MACHO
OGLE-SMC-ECL-1407	50851.95315	0.00580	Sec	B+R	MACHO
OGLE-SMC-ECL-1407	51499.96102	0.00528	Prim	B+R	MACHO
OGLE-SMC-ECL-1407	51501.07678	0.01308	Sec	B+R	MACHO
OGLE-SMC-ECL-1407	52199.54100	0.00251	Prim	I	OGLE III
OGLE-SMC-ECL-1407	52200.59766	0.00496	Sec	I	OGLE III
OGLE-SMC-ECL-1407	52575.58581	0.00118	Prim	I	OGLE III
OGLE-SMC-ECL-1407	52576.61588	0.00614	Sec	I	OGLE III
OGLE-SMC-ECL-1407	52924.32346	0.00232	Prim	I	OGLE III
OGLE-SMC-ECL-1407	52925.31293	0.00140	Sec	I	OGLE III
OGLE-SMC-ECL-1407	53300.37128	0.00145	Prim	I	OGLE III
OGLE-SMC-ECL-1407	53301.33887	0.00320	Sec	I	OGLE III
OGLE-SMC-ECL-1407	53649.10211	0.00177	Prim	I	OGLE III
OGLE-SMC-ECL-1407	53650.06528	0.00404	Sec	I	OGLE III
OGLE-SMC-ECL-1407	53999.94323	0.00416	Prim	I	OGLE III
OGLE-SMC-ECL-1407	54000.85550	0.00555	Sec	I	OGLE III
OGLE-SMC-ECL-1407	54350.77939	0.00263	Prim	I	OGLE III
OGLE-SMC-ECL-1407	54351.69302	0.00463	Sec	I	OGLE III
OGLE-SMC-ECL-1407	54800.35016	0.00327	Prim	I	OGLE III
OGLE-SMC-ECL-1407	54801.23674	0.00381	Sec	I	OGLE III
OGLE-SMC-ECL-1407	56640.64137	0.00119	Prim	R	DK154
OGLE-SMC-ECL-1407	56706.62008	0.00212	Sec	R	DK154
OGLE-SMC-ECL-2186	48701.09378	0.00523	Prim	B+R	MACHO
OGLE-SMC-ECL-2186	48702.98665	0.01720	Sec	B+R	MACHO
OGLE-SMC-ECL-2186	49550.25484	0.00192	Prim	B+R	MACHO
OGLE-SMC-ECL-2186	49552.13771	0.01594	Sec	B+R	MACHO
OGLE-SMC-ECL-2186	49849.77123	0.00794	Prim	B+R	MACHO
OGLE-SMC-ECL-2186	49851.64007	0.02195	Sec	B+R	MACHO
OGLE-SMC-ECL-2186	50198.66440	0.00176	Prim	B+R	MACHO
OGLE-SMC-ECL-2186	50200.50302	0.00638	Sec	B+R	MACHO
OGLE-SMC-ECL-2186	50550.84602	0.00851	Prim	B+R	MACHO
OGLE-SMC-ECL-2186	50552.66865	0.01982	Sec	B+R	MACHO
OGLE-SMC-ECL-2186	50850.36453	0.01027	Prim	B+R	MACHO
OGLE-SMC-ECL-2186	50852.16776	0.00809	Sec	B+R	MACHO
OGLE-SMC-ECL-2186	51498.76490	0.00206	Prim	B+R	MACHO
OGLE-SMC-ECL-2186	51500.54160	0.00316	Sec	B+R	MACHO
OGLE-SMC-ECL-2186	50748.32719	0.00435	Prim	I	OGLE III
OGLE-SMC-ECL-2186	50750.11970	0.00500	Sec	I	OGLE III
OGLE-SMC-ECL-2186	51699.53127	0.00179	Prim	I	OGLE III
OGLE-SMC-ECL-2186	51701.28957	0.00242	Sec	I	OGLE III
OGLE-SMC-ECL-2186	52199.83143	0.00657	Prim	I	OGLE III
OGLE-SMC-ECL-2186	52201.54632	0.00741	Sec	I	OGLE III
OGLE-SMC-ECL-2186	52575.06110	0.00450	Prim	I	OGLE III
OGLE-SMC-ECL-2186	52576.73683	0.00513	Sec	I	OGLE III
OGLE-SMC-ECL-2186	52923.96294	0.00808	Prim	I	OGLE III
OGLE-SMC-ECL-2186	52925.60931	0.00509	Sec	I	OGLE III
OGLE-SMC-ECL-2186	53299.17085	0.00203	Prim	I	OGLE III
OGLE-SMC-ECL-2186	53300.80791	0.00373	Sec	I	OGLE III
OGLE-SMC-ECL-2186	53651.34727	0.00639	Prim	I	OGLE III
OGLE-SMC-ECL-2186	53652.96525	0.00485	Sec	I	OGLE III
OGLE-SMC-ECL-2186	54000.22926	0.00325	Prim	I	OGLE III
OGLE-SMC-ECL-2186	54001.83984	0.00567	Sec	I	OGLE III
OGLE-SMC-ECL-2186	54349.12883	0.00566	Prim	I	OGLE III
OGLE-SMC-ECL-2186	54350.69183	0.00641	Sec	I	OGLE III
OGLE-SMC-ECL-2186	54800.04630	0.00450	Prim	I	OGLE III
OGLE-SMC-ECL-2186	54801.58628	0.00743	Sec	I	OGLE III
OGLE-SMC-ECL-2186	56669.56854	0.00091	Prim	R	DK154
OGLE-SMC-ECL-2186	56677.58220	0.00066	Sec	R	DK154
OGLE-SMC-ECL-2225	48699.87030	0.00966	Prim	B+R	MACHO

TABLE 8
LIST OF THE MINIMA TIMINGS USED FOR THE ANALYSIS.

Star	JD Hel.- 2400000	Error [day]	Type	Filter	Source / Observatory
OGLE-SMC-ECL-2225	48700.45057	0.00607	Sec	B+R	MACHO
OGLE-SMC-ECL-2225	49550.14572	0.00366	Prim	B+R	MACHO
OGLE-SMC-ECL-2225	49550.73392	0.00506	Sec	B+R	MACHO
OGLE-SMC-ECL-2225	49849.97432	0.00275	Prim	B+R	MACHO
OGLE-SMC-ECL-2225	49850.58771	0.00696	Sec	B+R	MACHO
OGLE-SMC-ECL-2225	50200.52770	0.00631	Prim	B+R	MACHO
OGLE-SMC-ECL-2225	50201.12738	0.00641	Sec	B+R	MACHO
OGLE-SMC-ECL-2225	50549.57873	0.01289	Prim	B+R	MACHO
OGLE-SMC-ECL-2225	50550.20266	0.00979	Sec	B+R	MACHO
OGLE-SMC-ECL-2225	50849.39455	0.00747	Prim	B+R	MACHO
OGLE-SMC-ECL-2225	50850.04827	0.00596	Sec	B+R	MACHO
OGLE-SMC-ECL-2225	51499.76771	0.02076	Prim	B+R	MACHO
OGLE-SMC-ECL-2225	51500.44540	0.02053	Sec	B+R	MACHO
OGLE-SMC-ECL-2225	52199.34712	0.00252	Prim	I	OGLE III
OGLE-SMC-ECL-2225	52200.10630	0.01075	Sec	I	OGLE III
OGLE-SMC-ECL-2225	52575.25680	0.00215	Prim	I	OGLE III
OGLE-SMC-ECL-2225	52576.02555	0.00544	Sec	I	OGLE III
OGLE-SMC-ECL-2225	52924.29983	0.00319	Prim	I	OGLE III
OGLE-SMC-ECL-2225	52925.10071	0.00252	Sec	I	OGLE III
OGLE-SMC-ECL-2225	53300.20601	0.00534	Prim	I	OGLE III
OGLE-SMC-ECL-2225	53301.02592	0.00359	Sec	I	OGLE III
OGLE-SMC-ECL-2225	53649.24349	0.00271	Prim	I	OGLE III
OGLE-SMC-ECL-2225	53650.10421	0.00207	Sec	I	OGLE III
OGLE-SMC-ECL-2225	53999.78851	0.00337	Prim	I	OGLE III
OGLE-SMC-ECL-2225	54000.67118	0.00923	Sec	I	OGLE III
OGLE-SMC-ECL-2225	54350.35287	0.00291	Prim	I	OGLE III
OGLE-SMC-ECL-2225	54351.22518	0.00150	Sec	I	OGLE III
OGLE-SMC-ECL-2225	54799.33928	0.00355	Prim	I	OGLE III
OGLE-SMC-ECL-2225	54800.24310	0.00304	Sec	I	OGLE III
OGLE-SMC-ECL-2225	56641.62568	0.00099	Prim	R	DK154
OGLE-SMC-ECL-2225	56677.43050	0.00213	Prim	R	DK154
OGLE-SMC-ECL-2225	56706.66141	0.00932	Sec	R	DK154
OGLE-SMC-ECL-2225	56727.57026	0.00856	Sec	R	DK154
OGLE-SMC-ECL-2225	56739.49729	0.00448	Sec	R	DK154
OGLE-SMC-ECL-2251	50750.22871	0.01111	Prim	I	OGLE II
OGLE-SMC-ECL-2251	50751.76132	0.00909	Sec	I	OGLE II
OGLE-SMC-ECL-2251	51701.03998	0.00534	Prim	I	OGLE II
OGLE-SMC-ECL-2251	51702.49569	0.00466	Sec	I	OGLE II
OGLE-SMC-ECL-2251	52200.98659	0.00419	Prim	I	OGLE III
OGLE-SMC-ECL-2251	52202.35316	0.00760	Sec	I	OGLE III
OGLE-SMC-ECL-2251	52574.77804	0.00435	Prim	I	OGLE III
OGLE-SMC-ECL-2251	52576.09912	0.01312	Sec	I	OGLE III
OGLE-SMC-ECL-2251	52925.18554	0.00564	Prim	I	OGLE III
OGLE-SMC-ECL-2251	52926.45681	0.02329	Sec	I	OGLE III
OGLE-SMC-ECL-2251	53298.99286	0.00406	Prim	I	OGLE III
OGLE-SMC-ECL-2251	53300.22628	0.02132	Sec	I	OGLE III
OGLE-SMC-ECL-2251	53649.40932	0.00442	Prim	I	OGLE III
OGLE-SMC-ECL-2251	53650.58269	0.00382	Sec	I	OGLE III
OGLE-SMC-ECL-2251	53999.83046	0.00299	Prim	I	OGLE III
OGLE-SMC-ECL-2251	54000.94196	0.00673	Sec	I	OGLE III
OGLE-SMC-ECL-2251	54350.26571	0.00468	Prim	I	OGLE III
OGLE-SMC-ECL-2251	54351.32752	0.03865	Sec	I	OGLE III
OGLE-SMC-ECL-2251	54801.13489	0.00506	Prim	I	OGLE III
OGLE-SMC-ECL-2251	54802.18335	0.01739	Sec	I	OGLE III
OGLE-SMC-ECL-2251	56639.69916	0.00113	Prim	R	DK154
OGLE-SMC-ECL-2251	56675.56777	0.00287	Sec	R	DK154
OGLE-SMC-ECL-2251	56689.57815	0.00124	Sec	R	DK154
OGLE-SMC-ECL-2524	48749.05117	0.00480	Prim	B+R	MACHO
OGLE-SMC-ECL-2524	48750.47954	0.00177	Sec	B+R	MACHO
OGLE-SMC-ECL-2524	49749.07351	0.00122	Prim	B+R	MACHO
OGLE-SMC-ECL-2524	49750.50676	0.00382	Sec	B+R	MACHO
OGLE-SMC-ECL-2524	50250.18009	0.00171	Prim	B+R	MACHO
OGLE-SMC-ECL-2524	50251.61017	0.00254	Sec	B+R	MACHO
OGLE-SMC-ECL-2524	50749.11909	0.00208	Prim	B+R	MACHO
OGLE-SMC-ECL-2524	50750.53425	0.00654	Sec	B+R	MACHO
OGLE-SMC-ECL-2524	51499.69730	0.00381	Prim	B+R	MACHO
OGLE-SMC-ECL-2524	51501.07663	0.00180	Sec	B+R	MACHO
OGLE-SMC-ECL-2524	52200.40699	0.00311	Prim	I	OGLE III
OGLE-SMC-ECL-2524	52201.70247	0.00847	Sec	I	OGLE III
OGLE-SMC-ECL-2524	52575.70108	0.00258	Prim	I	OGLE III
OGLE-SMC-ECL-2524	52576.96208	0.00417	Sec	I	OGLE III
OGLE-SMC-ECL-2524	52924.96844	0.00138	Prim	I	OGLE III
OGLE-SMC-ECL-2524	52926.17872	0.00242	Sec	I	OGLE III
OGLE-SMC-ECL-2524	53300.26282	0.00111	Prim	I	OGLE III
OGLE-SMC-ECL-2524	53301.42517	0.00349	Sec	I	OGLE III
OGLE-SMC-ECL-2524	53649.53104	0.00122	Prim	I	OGLE III
OGLE-SMC-ECL-2524	53650.64581	0.00225	Sec	I	OGLE III
OGLE-SMC-ECL-2524	54000.95733	0.00455	Prim	I	OGLE III
OGLE-SMC-ECL-2524	54002.02888	0.00174	Sec	I	OGLE III
OGLE-SMC-ECL-2524	54350.23684	0.00791	Prim	I	OGLE III
OGLE-SMC-ECL-2524	54351.24487	0.00204	Sec	I	OGLE III

TABLE 9
LIST OF THE MINIMA TIMINGS USED FOR THE ANALYSIS.

Star	JD Hel.- 2400000	Error [day]	Type	Filter	Source / Observatory
OGLE-SMC-ECL-2524	54799.30059	0.00479	Prim	I	OGLE III
OGLE-SMC-ECL-2524	54800.24413	0.00068	Sec	I	OGLE III
OGLE-SMC-ECL-2524	56639.65255	0.00061	Sec	R	DK154
OGLE-SMC-ECL-2524	56673.59328	0.00059	Prim	R	DK154
OGLE-SMC-ECL-2524	56689.54270	0.00350	Sec	R	DK154
OGLE-SMC-ECL-2534	48800.83606	0.00410	Prim	B+R	MACHO
OGLE-SMC-ECL-2534	48801.88294	0.01385	Sec	B+R	MACHO
OGLE-SMC-ECL-2534	49799.92570	0.00731	Prim	B+R	MACHO
OGLE-SMC-ECL-2534	49800.96534	0.00873	Sec	B+R	MACHO
OGLE-SMC-ECL-2534	50199.53392	0.01529	Prim	B+R	MACHO
OGLE-SMC-ECL-2534	50200.59122	0.00513	Sec	B+R	MACHO
OGLE-SMC-ECL-2534	50550.94672	0.01128	Prim	B+R	MACHO
OGLE-SMC-ECL-2534	50552.00100	0.01895	Sec	B+R	MACHO
OGLE-SMC-ECL-2534	50849.50052	0.00706	Prim	B+R	MACHO
OGLE-SMC-ECL-2534	50850.58736	0.02162	Sec	B+R	MACHO
OGLE-SMC-ECL-2534	51499.48078	0.02502	Prim	B+R	MACHO
OGLE-SMC-ECL-2534	51500.57635	0.01736	Sec	B+R	MACHO
OGLE-SMC-ECL-2534	52199.97862	0.00262	Prim	I	OGLE III
OGLE-SMC-ECL-2534	52201.08392	0.00473	Sec	I	OGLE III
OGLE-SMC-ECL-2534	52574.34158	0.00194	Prim	I	OGLE III
OGLE-SMC-ECL-2534	52575.45897	0.00952	Sec	I	OGLE III
OGLE-SMC-ECL-2534	52925.72595	0.00185	Prim	I	OGLE III
OGLE-SMC-ECL-2534	52926.85598	0.00211	Sec	I	OGLE III
OGLE-SMC-ECL-2534	53300.09757	0.00093	Prim	I	OGLE III
OGLE-SMC-ECL-2534	53301.23659	0.00496	Sec	I	OGLE III
OGLE-SMC-ECL-2534	53649.19553	0.00172	Prim	I	OGLE III
OGLE-SMC-ECL-2534	53650.34464	0.00781	Sec	I	OGLE III
OGLE-SMC-ECL-2534	54000.59273	0.00031	Prim	I	OGLE III
OGLE-SMC-ECL-2534	54001.74718	0.00343	Sec	I	OGLE III
OGLE-SMC-ECL-2534	54349.68687	0.00154	Prim	I	OGLE III
OGLE-SMC-ECL-2534	54350.86174	0.00322	Sec	I	OGLE III
OGLE-SMC-ECL-2534	54799.84807	0.00475	Prim	I	OGLE III
OGLE-SMC-ECL-2534	54801.03243	0.01016	Sec	I	OGLE III
OGLE-SMC-ECL-3594	48751.03362	0.00612	Prim	B+R	MACHO
OGLE-SMC-ECL-3594	48752.73313	0.00487	Sec	B+R	MACHO
OGLE-SMC-ECL-3594	49651.74109	0.00235	Prim	B+R	MACHO
OGLE-SMC-ECL-3594	49653.46092	0.00449	Sec	B+R	MACHO
OGLE-SMC-ECL-3594	49998.15595	0.00554	Prim	B+R	MACHO
OGLE-SMC-ECL-3594	49999.88282	0.00592	Sec	B+R	MACHO
OGLE-SMC-ECL-3594	50348.91199	0.00310	Prim	B+R	MACHO
OGLE-SMC-ECL-3594	50350.65164	0.01405	Sec	B+R	MACHO
OGLE-SMC-ECL-3594	50652.02791	0.00688	Prim	B+R	MACHO
OGLE-SMC-ECL-3594	50653.78149	0.00711	Sec	B+R	MACHO
OGLE-SMC-ECL-3594	50950.81588	0.00496	Prim	B+R	MACHO
OGLE-SMC-ECL-3594	50952.56833	0.00282	Sec	B+R	MACHO
OGLE-SMC-ECL-3594	51548.38929	0.00442	Prim	B+R	MACHO
OGLE-SMC-ECL-3594	51550.18670	0.00918	Sec	B+R	MACHO
OGLE-SMC-ECL-3594	52202.24613	0.00398	Prim	I	OGLE III
OGLE-SMC-ECL-3594	52204.07478	0.00003	Sec	I	OGLE III
OGLE-SMC-ECL-3594	52574.64781	0.00245	Prim	I	OGLE III
OGLE-SMC-ECL-3594	52576.49461	0.00434	Sec	I	OGLE III
OGLE-SMC-ECL-3594	52925.39286	0.00217	Prim	I	OGLE III
OGLE-SMC-ECL-3594	52927.26649	0.00003	Sec	I	OGLE III
OGLE-SMC-ECL-3594	53302.12389	0.00793	Prim	I	OGLE III
OGLE-SMC-ECL-3594	53304.00261	0.00601	Sec	I	OGLE III
OGLE-SMC-ECL-3594	53648.54075	0.00042	Prim	I	OGLE III
OGLE-SMC-ECL-3594	53650.43839	0.00270	Sec	I	OGLE III
OGLE-SMC-ECL-3594	53999.28473	0.00329	Prim	I	OGLE III
OGLE-SMC-ECL-3594	54001.21997	0.00223	Sec	I	OGLE III
OGLE-SMC-ECL-3594	54350.03062	0.00353	Prim	I	OGLE III
OGLE-SMC-ECL-3594	54351.97934	0.00245	Sec	I	OGLE III
OGLE-SMC-ECL-3594	54800.37520	0.00173	Prim	I	OGLE III
OGLE-SMC-ECL-3594	54802.34160	0.00842	Sec	I	OGLE III
OGLE-SMC-ECL-3677	48699.80729	0.01272	Sec	B+R	MACHO
OGLE-SMC-ECL-3677	48701.90985	0.01951	Prim	B+R	MACHO
OGLE-SMC-ECL-3677	49548.92971	0.01937	Sec	B+R	MACHO
OGLE-SMC-ECL-3677	49551.04309	0.00854	Prim	B+R	MACHO
OGLE-SMC-ECL-3677	49847.71464	0.02852	Sec	B+R	MACHO
OGLE-SMC-ECL-3677	49849.81264	0.01114	Prim	B+R	MACHO
OGLE-SMC-ECL-3677	50198.88911	0.01522	Sec	B+R	MACHO
OGLE-SMC-ECL-3677	50201.00269	0.01166	Prim	B+R	MACHO
OGLE-SMC-ECL-3677	50550.07712	0.02286	Sec	B+R	MACHO
OGLE-SMC-ECL-3677	50552.19617	0.01038	Prim	B+R	MACHO
OGLE-SMC-ECL-3677	50848.82438	0.02664	Sec	B+R	MACHO
OGLE-SMC-ECL-3677	50850.97001	0.00644	Prim	B+R	MACHO
OGLE-SMC-ECL-3677	51498.77983	0.02237	Sec	B+R	MACHO
OGLE-SMC-ECL-3677	51500.92187	0.00895	Prim	B+R	MACHO
OGLE-SMC-ECL-3677	52201.14249	0.01502	Sec	I	OGLE III
OGLE-SMC-ECL-3677	52203.31297	0.00469	Prim	I	OGLE III
OGLE-SMC-ECL-3677	52573.27233	0.00763	Sec	I	OGLE III
OGLE-SMC-ECL-3677	52575.46868	0.00569	Prim	I	OGLE III

TABLE 10
LIST OF THE MINIMA TIMINGS USED FOR THE ANALYSIS.

Star	JD Hel.- 2400000	Error [day]	Type	Filter	Source / Observatory
OGLE-SMC-ECL-3677	52924.45135	0.00696	Sec	I	OGLE III
OGLE-SMC-ECL-3677	52926.65837	0.00648	Prim	I	OGLE III
OGLE-SMC-ECL-3677	53301.81466	0.01272	Sec	I	OGLE III
OGLE-SMC-ECL-3677	53304.07030	0.00956	Prim	I	OGLE III
OGLE-SMC-ECL-3677	53647.75372	0.01490	Sec	I	OGLE III
OGLE-SMC-ECL-3677	53650.01979	0.00356	Prim	I	OGLE III
OGLE-SMC-ECL-3677	53998.92989	0.01257	Sec	I	OGLE III
OGLE-SMC-ECL-3677	54001.21811	0.00470	Prim	I	OGLE III
OGLE-SMC-ECL-3677	54350.11175	0.01169	Sec	I	OGLE III
OGLE-SMC-ECL-3677	54352.39886	0.00198	Prim	I	OGLE III
OGLE-SMC-ECL-3677	54800.87834	0.00487	Sec	I	OGLE III
OGLE-SMC-ECL-3677	54803.18740	0.00587	Prim	I	OGLE III
OGLE-SMC-ECL-3951	50548.54640	0.00520	Prim	I	OGLE II
OGLE-SMC-ECL-3951	50550.20977	0.00469	Sec	I	OGLE II
OGLE-SMC-ECL-3951	51101.11593	0.00465	Prim	I	OGLE II
OGLE-SMC-ECL-3951	51102.74425	0.00397	Sec	I	OGLE II
OGLE-SMC-ECL-3951	51700.25361	0.00386	Prim	I	OGLE II
OGLE-SMC-ECL-3951	51701.88334	0.00627	Sec	I	OGLE II
OGLE-SMC-ECL-3951	52200.06093	0.00382	Prim	I	OGLE III
OGLE-SMC-ECL-3951	52201.66655	0.00436	Sec	I	OGLE III
OGLE-SMC-ECL-3951	52575.68577	0.00775	Prim	I	OGLE III
OGLE-SMC-ECL-3951	52577.27291	0.00530	Sec	I	OGLE III
OGLE-SMC-ECL-3951	52926.47673	0.00762	Prim	I	OGLE III
OGLE-SMC-ECL-3951	52928.03171	0.00860	Sec	I	OGLE III
OGLE-SMC-ECL-3951	53298.99469	0.00262	Prim	I	OGLE III
OGLE-SMC-ECL-3951	53300.53536	0.00247	Sec	I	OGLE III
OGLE-SMC-ECL-3951	53649.79107	0.00178	Prim	I	OGLE III
OGLE-SMC-ECL-3951	53651.30663	0.00770	Sec	I	OGLE III
OGLE-SMC-ECL-3951	54000.58489	0.00707	Prim	I	OGLE III
OGLE-SMC-ECL-3951	54002.10747	0.00979	Sec	I	OGLE III
OGLE-SMC-ECL-3951	54351.38258	0.00162	Prim	I	OGLE III
OGLE-SMC-ECL-3951	54352.86482	0.00654	Sec	I	OGLE III
OGLE-SMC-ECL-3951	54801.52124	0.00479	Prim	I	OGLE III
OGLE-SMC-ECL-3951	54802.98917	0.01250	Sec	I	OGLE III
OGLE-SMC-ECL-4955	48750.12518	0.00631	Prim	B+R	MACHO
OGLE-SMC-ECL-4955	48751.38801	0.02229	Sec	B+R	MACHO
OGLE-SMC-ECL-4955	49651.08861	0.00532	Prim	B+R	MACHO
OGLE-SMC-ECL-4955	49652.33413	0.03385	Sec	B+R	MACHO
OGLE-SMC-ECL-4955	50000.39638	0.00395	Prim	B+R	MACHO
OGLE-SMC-ECL-4955	50001.62993	0.02874	Sec	B+R	MACHO
OGLE-SMC-ECL-4955	50349.71256	0.00389	Prim	B+R	MACHO
OGLE-SMC-ECL-4955	50350.87651	0.01422	Sec	B+R	MACHO
OGLE-SMC-ECL-4955	50649.11491	0.00313	Prim	B+R	MACHO
OGLE-SMC-ECL-4955	50650.25954	0.01288	Sec	B+R	MACHO
OGLE-SMC-ECL-4955	50951.29501	0.00429	Prim	B+R	MACHO
OGLE-SMC-ECL-4955	50952.44016	0.01871	Sec	B+R	MACHO
OGLE-SMC-ECL-4955	51550.09921	0.00687	Prim	B+R	MACHO
OGLE-SMC-ECL-4955	51551.18926	0.01608	Sec	B+R	MACHO
OGLE-SMC-ECL-4955	52198.83073	0.00972	Prim	I	OGLE III
OGLE-SMC-ECL-4955	52199.82288	0.00238	Sec	I	OGLE III
OGLE-SMC-ECL-4955	52575.85660	0.00253	Prim	I	OGLE III
OGLE-SMC-ECL-4955	52576.84703	0.00743	Sec	I	OGLE III
OGLE-SMC-ECL-4955	52925.15650	0.00209	Prim	I	OGLE III
OGLE-SMC-ECL-4955	52926.11742	0.00000	Sec	I	OGLE III
OGLE-SMC-ECL-4955	53299.40496	0.00020	Prim	I	OGLE III
OGLE-SMC-ECL-4955	53300.35027	0.00720	Sec	I	OGLE III
OGLE-SMC-ECL-4955	53651.48950	0.00772	Prim	I	OGLE III
OGLE-SMC-ECL-4955	53652.42259	0.00203	Sec	I	OGLE III
OGLE-SMC-ECL-4955	54000.79736	0.00435	Prim	I	OGLE III
OGLE-SMC-ECL-4955	54001.70010	0.00418	Sec	I	OGLE III
OGLE-SMC-ECL-4955	54350.10388	0.00792	Prim	I	OGLE III
OGLE-SMC-ECL-4955	54350.99198	0.00293	Sec	I	OGLE III
OGLE-SMC-ECL-4955	54799.20041	0.00141	Prim	I	OGLE III
OGLE-SMC-ECL-4955	54800.08989	0.00558	Sec	I	OGLE III
OGLE-SMC-ECL-5233	52198.73233	0.00798	Prim	I	OGLE III
OGLE-SMC-ECL-5233	52201.92612	0.00000	Sec	I	OGLE III
OGLE-SMC-ECL-5233	52573.81356	0.00377	Prim	I	OGLE III
OGLE-SMC-ECL-5233	52576.99968	0.00250	Sec	I	OGLE III
OGLE-SMC-ECL-5233	52923.55994	0.01665	Prim	I	OGLE III
OGLE-SMC-ECL-5233	52926.74636	0.00955	Sec	I	OGLE III
OGLE-SMC-ECL-5233	53298.63156	0.00478	Prim	I	OGLE III
OGLE-SMC-ECL-5233	53301.76315	0.00548	Sec	I	OGLE III
OGLE-SMC-ECL-5233	53648.41252	0.03105	Prim	I	OGLE III
OGLE-SMC-ECL-5233	53651.42894	0.00478	Sec	I	OGLE III
OGLE-SMC-ECL-5233	53998.17633	0.01331	Prim	I	OGLE III
OGLE-SMC-ECL-5233	54001.10599	0.00849	Sec	I	OGLE III
OGLE-SMC-ECL-5233	54347.97205	0.00515	Prim	I	OGLE III
OGLE-SMC-ECL-5233	54350.74730	0.01452	Sec	I	OGLE III
OGLE-SMC-ECL-5233	54799.11105	0.02745	Prim	I	OGLE III
OGLE-SMC-ECL-5233	54801.71854	0.00803	Sec	I	OGLE III
OGLE-SMC-ECL-5233	48747.75771	0.02284	Prim	B+R	MACHO

TABLE 11
LIST OF THE MINIMA TIMINGS USED FOR THE ANALYSIS.

Star	JD Hel.- 2400000	Error [day]	Type	Filter	Source / Observatory
OGLE-SMC-ECL-5233	48749.89493	0.01255	Sec	B+R	MACHO
OGLE-SMC-ECL-5233	49751.21107	0.01683	Prim	B+R	MACHO
OGLE-SMC-ECL-5233	49753.48924	0.01297	Sec	B+R	MACHO
OGLE-SMC-ECL-5233	50247.75172	0.03015	Prim	B+R	MACHO
OGLE-SMC-ECL-5233	50250.30258	0.00997	Sec	B+R	MACHO
OGLE-SMC-ECL-5233	50749.41555	0.00521	Prim	B+R	MACHO
OGLE-SMC-ECL-5233	50752.16203	0.01977	Sec	B+R	MACHO
OGLE-SMC-ECL-5233	51499.37910	0.01377	Prim	B+R	MACHO
OGLE-SMC-ECL-5233	51502.33500	0.00936	Sec	B+R	MACHO
OGLE-SMC-ECL-5233	56669.66164	0.00089	Prim	R	DK154
OGLE-SMC-ECL-5233	56676.65528	0.00095	Sec	R	DK154
OGLE-SMC-ECL-5422	48701.27481	0.00746	Prim	B+R	MACHO1+2
OGLE-SMC-ECL-5422	48702.82150	0.02491	Sec	B+R	MACHO1+2
OGLE-SMC-ECL-5422	49549.49972	0.01280	Prim	B+R	MACHO1+2
OGLE-SMC-ECL-5422	49551.05868	0.00682	Sec	B+R	MACHO1+2
OGLE-SMC-ECL-5422	49850.48551	0.00818	Prim	B+R	MACHO1+2
OGLE-SMC-ECL-5422	49852.05883	0.00491	Sec	B+R	MACHO1+2
OGLE-SMC-ECL-5422	50200.10518	0.00840	Prim	B+R	MACHO1+2
OGLE-SMC-ECL-5422	50201.70786	0.01002	Sec	B+R	MACHO1+2
OGLE-SMC-ECL-5422	50549.72721	0.00918	Prim	B+R	MACHO1+2
OGLE-SMC-ECL-5422	50551.35470	0.00736	Sec	B+R	MACHO1+2
OGLE-SMC-ECL-5422	50850.70503	0.00509	Prim	B+R	MACHO1+2
OGLE-SMC-ECL-5422	50852.35616	0.00474	Sec	B+R	MACHO1+2
OGLE-SMC-ECL-5422	51501.30424	0.01298	Prim	B+R	MACHO1+2
OGLE-SMC-ECL-5422	51502.98810	0.00716	Sec	B+R	MACHO1+2
OGLE-SMC-ECL-5422	50549.70892	0.00210	Prim	I	OGLE II
OGLE-SMC-ECL-5422	50551.35676	0.00230	Sec	I	OGLE II
OGLE-SMC-ECL-5422	51099.98977	0.00336	Prim	I	OGLE II
OGLE-SMC-ECL-5422	51101.66027	0.00092	Sec	I	OGLE II
OGLE-SMC-ECL-5422	51698.90939	0.00154	Prim	I	OGLE II
OGLE-SMC-ECL-5422	51700.61184	0.00215	Sec	I	OGLE II
OGLE-SMC-ECL-5422	52200.54217	0.00385	Prim	I	OGLE III
OGLE-SMC-ECL-5422	52202.27954	0.00557	Sec	I	OGLE III
OGLE-SMC-ECL-5422	52574.48865	0.00266	Prim	I	OGLE III
OGLE-SMC-ECL-5422	52576.25467	0.00306	Sec	I	OGLE III
OGLE-SMC-ECL-5422	52924.11355	0.00205	Prim	I	OGLE III
OGLE-SMC-ECL-5422	52925.89530	0.00320	Sec	I	OGLE III
OGLE-SMC-ECL-5422	53301.10369	0.00275	Prim	I	OGLE III
OGLE-SMC-ECL-5422	53302.89816	0.00329	Sec	I	OGLE III
OGLE-SMC-ECL-5422	53650.71277	0.00982	Prim	I	OGLE III
OGLE-SMC-ECL-5422	53652.53418	0.00438	Sec	I	OGLE III
OGLE-SMC-ECL-5422	54000.35282	0.00120	Prim	I	OGLE III
OGLE-SMC-ECL-5422	54002.17710	0.00006	Sec	I	OGLE III
OGLE-SMC-ECL-5422	54349.98870	0.00116	Prim	I	OGLE III
OGLE-SMC-ECL-5422	54351.81853	0.00001	Sec	I	OGLE III
OGLE-SMC-ECL-5422	54799.94233	0.00889	Prim	I	OGLE III
OGLE-SMC-ECL-5422	54801.77785	0.00402	Sec	I	OGLE III
OGLE-SMC-ECL-5434	48798.94606	0.01483	Prim	B+R	MACHO
OGLE-SMC-ECL-5434	48800.47699	0.00603	Sec	B+R	MACHO
OGLE-SMC-ECL-5434	49800.72760	0.00678	Prim	B+R	MACHO
OGLE-SMC-ECL-5434	49802.25181	0.01099	Sec	B+R	MACHO
OGLE-SMC-ECL-5434	50199.12527	0.01339	Prim	B+R	MACHO
OGLE-SMC-ECL-5434	50200.65017	0.00750	Sec	B+R	MACHO
OGLE-SMC-ECL-5434	50551.33912	0.00586	Prim	B+R	MACHO
OGLE-SMC-ECL-5434	50552.84222	0.01509	Sec	B+R	MACHO
OGLE-SMC-ECL-5434	50848.71070	0.00518	Prim	B+R	MACHO
OGLE-SMC-ECL-5434	50850.18788	0.01259	Sec	B+R	MACHO
OGLE-SMC-ECL-5434	51501.15782	0.00807	Prim	B+R	MACHO
OGLE-SMC-ECL-5434	51502.62719	0.02513	Sec	B+R	MACHO
OGLE-SMC-ECL-5434	50551.33644	0.00503	Prim	I	OGLE II
OGLE-SMC-ECL-5434	50552.82479	0.00705	Sec	I	OGLE II
OGLE-SMC-ECL-5434	51099.85925	0.02141	Prim	I	OGLE II
OGLE-SMC-ECL-5434	51101.33185	0.01155	Sec	I	OGLE II
OGLE-SMC-ECL-5434	51700.34958	0.00445	Prim	I	OGLE II
OGLE-SMC-ECL-5434	51701.82145	0.00903	Sec	I	OGLE II
OGLE-SMC-ECL-5434	52199.81176	0.00436	Prim	I	OGLE III
OGLE-SMC-ECL-5434	52201.23825	0.00482	Sec	I	OGLE III
OGLE-SMC-ECL-5434	52575.12842	0.00442	Prim	I	OGLE III
OGLE-SMC-ECL-5434	52576.53465	0.00466	Sec	I	OGLE III
OGLE-SMC-ECL-5434	52924.44326	0.00311	Prim	I	OGLE III
OGLE-SMC-ECL-5434	52925.84853	0.00567	Sec	I	OGLE III
OGLE-SMC-ECL-5434	53299.75304	0.00310	Prim	I	OGLE III
OGLE-SMC-ECL-5434	53301.15126	0.00369	Sec	I	OGLE III
OGLE-SMC-ECL-5434	53649.08118	0.00282	Prim	I	OGLE III
OGLE-SMC-ECL-5434	53650.46107	0.00647	Sec	I	OGLE III
OGLE-SMC-ECL-5434	54001.28546	0.00260	Prim	I	OGLE III
OGLE-SMC-ECL-5434	54002.65242	0.00208	Sec	I	OGLE III
OGLE-SMC-ECL-5434	54350.61859	0.00245	Prim	I	OGLE III
OGLE-SMC-ECL-5434	54351.97724	0.00573	Sec	I	OGLE III
OGLE-SMC-ECL-5434	54800.98529	0.00261	Prim	I	OGLE III
OGLE-SMC-ECL-5434	54802.33139	0.00413	Sec	I	OGLE III